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Technical Note Nr. 3

Tunnel Temperature Evaluation for the SNS Tunnel

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Abstract

This is a short description and estimate of the temperature tunnel rise during one operating year assuming 6000 h of operation at full power (dissipation) into the tunnel. The heat dissipated into the tunnel we heat up the air very quickly and it is being estimated how much power is dissipated from the tunnel through the wall into the surrounding earth.

Introduction and Basic Assumptions

The tunnel is assumed to be of rectangular shape, 14 x 10 ft, with a wall thickness of 18 inch (~50 cm). Dissipation will take place through three of the wall surfaces. The fourth surface is assumed to be perfectly insulated, because in reality it is embedded into a light concrete fill. A sketch is shown in the following figure.

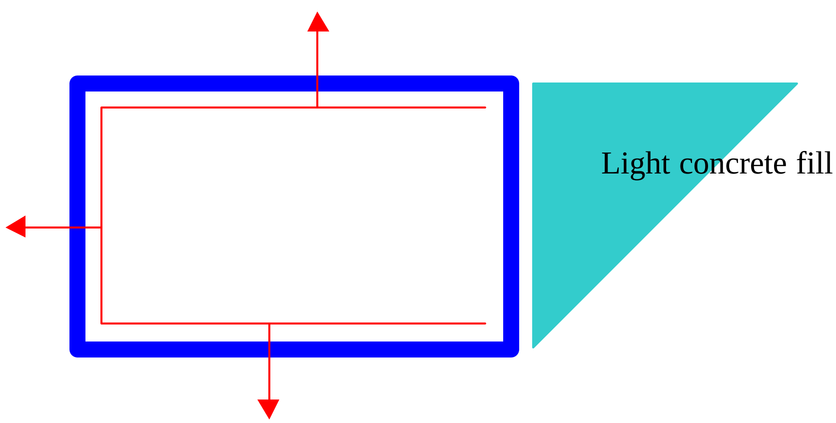

Figure 1: Cross section of the tunnel enclosure

Table of parameters used for the estimate		
Heat capacity of concrete	Joule/kg/Kelvin	880
Heat conduction coefficient	Watt/Kelvin/m	0.8-1.3 ~ 1.0
Temperature of clay	Deg F° [Deg C°]	55 [13]
Temperature of Tunnel inner walls	Deg F° [Deg C°]	85 [29]
Tunnel cross section	ft x ft [m x m]	10 x 14 [3 x 4.3]
Surface area per linear meter	m^2	11.6

Table 1: Parameters used for the estimate (decent units are used for ease of calculation).

Power Transfer Through the Wall

Under the assumption that the tunnel inner wall temperature as well as the clay stays at a constant temperature (see numbers in table 1) the power transfer can easily be calculated.

$$P = \lambda \cdot \frac{Surface}{wallthickness} \cdot \Delta T$$

$$P = 1 \cdot [\frac{W}{m \cdot K}] \cdot \frac{11.6}{0.5} \cdot 16$$

$$P = 370 \text{ Watt per linear meter of tunnel}$$

This value, 370 Watt per linear meter of tunnel corresponds to 32 Watts per m^2 or 3 Watts per sqft. From this simple calculation it is very clear that in principle a tunnel wall as thick as 0.5 meter (18 inch) can transfer a lot of power out of the tunnel. Much more then there is generated in the tunnel even next to the normal conducting linac. Remember that at a tunnel temperature of 85 deg F, the accelerating structure will absorb or at least not dissipate any more power into the air. If the tunnel temperature would get higher the structure would start absorbing power from the surrounding tunnel air. Since the medium surrounding the tunnel is dry and has no moving ground water, this simple estimate is not sufficient to answer the question on how much power actually is transferred.

Power Transfer Into the Berm

The berm surrounding the tunnel will absorb the power transferred through the wall and slowly heat up. When the temperature rises the heat transfer gets reduced because it is proportional to the temperature difference. This will clearly limit the amount of power possible to transmit through the wall. For a rough first order estimate the assumption is that Volume around the tunnel is limited to approximately 5 meters (17 feet). The heat capacity of the clay or gravel is assumed to be the same like concrete (see table 1). Therefore the surrounding earth will have to absorb and energy of:

$$E = P \cdot T_{operation}$$

$$E = 370 \cdot 2x10^7$$

$$E = 740 MJoule \text{ per meter of tunnel}$$

Since each meter of tunnel is surrounded by 11.6 x 5= 58 m^3 of dirt with a heat capacity of 880 J/kg/K and each m^3 is 2600 kg, the temperature rise over the year would be 60 $\deg C°$ (or going from 55 deg F to 165deg F°). This of course is unrealistic, on the other hand the earth is not confined to 5 meter. If the power transfer would only be 1/10 of 370 Watt =37 Watt per linear meter of tunnel, the temperature rise would only be 6 deg. Certainly a too small value. The transfer per sqft in this case would be 0.3 Watt, still higher than the value being given before (conversation on Friday Feb16th, 2001), which was ~ 0.1 Watt / sqft. So the value under a more realistic assumption will be in between 0.3 and 3 and probably closer to 0.3.

Summary

Estimates were presented to determine the heat dissipation for the tunnel enclosures. This very crude model indicates that the heat transfer through the wall will probably be of the order of 0.3-0.5 Watt per sqft, may be up to 1 Watt per sqft. Given the dissipation into the tunnel for the front end and linac part (see load sheet presented in the same meeting on Friday Feb16th, 2001), there should be no net cooling necessary to keep the tunnel temperature under control in the linac part. Since the model is very crude more sophisticated models could be applied, which might be useful in the HEBT, RTBT and Ring part where the loads are significantly higher.